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A PLAN TO DEVELOP PREDICTIVE CAPABILITY FOR EQUATORIAL SCINTILLATION STORMS

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LONG TERM GOALS

The emphasis of this study is on amplitude and phase scintillations near the magnetic equator and in the anomaly region which lies 15-20 degrees from the magnetic equator. Military communication satellites that are being launched have equipment which continue the presently available 250 MHz FLEETSAT and AFSATCOM systems as well as new spectral regions for communications.

Fading on signals on the 250 MHz transmissions from FLEETSAT and on 1.2 and 1.6 GHz transmissions from the Global Positioning System is the focus of the Boston University studies. 250 MHz transmissions often show deep fading to noise levels in equatorial latitudes during certain months and during years of sunspot maximum. Fading due to ionospheric irregularities on satellite signals in equatorial latitudes could be mitigated by various techniques if forecasting of these irregularities was in place. The aim of the studies is to determine what can be done to forecast scintillations. The emphasis is on observational parameters being used for forecasting.

It should be noted that many new systems both proposed and being set into operation utilize the L Band spectrum. This included Iridium as well as other systems proposed for personal communications.

SCIENTIFIC OBJECTIVES

Using data from optical and radio measurements, we intend to validate some theoretical studies of the physics of the development of irregularities. We use measurements of various ionospheric parameters to determine the necessary and sufficient conditions for instabilities to develop.

THE OCTOBER 1996 EQUATORIAL CAMPAIGN

At this time we have initiated a general study of the October 1996 period. This includes data from the first half of the month when optical data and phase scintillation data were obtained by Boston University and amplitude scintillations observations were made by Cornell University. For the second half of October we use GPS and radar data from Jicamarca and other sets of data such as soundings (University of Massachussetts-Lowell).

Much of the data have been reduced. The Julia radar data indicated the form of plumes and low altitude irregularity structure along the longitude of Jicamarca. The campaign month of October 1996 included a severe magnetic storm on the night of October 22-23, 2996. Effects were seen by GPS stations available thru the International Geodesy Service. The sites utilized include Arequipa, (Peru), Santiago, (Chile), Fortaleza, (Brazil), Kourou, (French Guiana), La Plata, (Argentina), and Brasilia, (Brazil). For the storm opf October 22-23 which produced a plume which extended as high as 1400 km and lasted for several hours, we have found evidence of phase fluctuations at longitudes beyond the eastern and western coasts of South America (at Ascension Island and Easter Island). This storm which had strong effects at anomoly latitudes all across South America would severely impair GPS measurements on some commercial receivers.

THere was a great variety of irregularity developments. Data were obtained with nights when no irregularities were observed at any location in the equatorial region across South America. There were nights when only localized irregularity structures with relatively narrow longitudinal effects were noted

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close to the magnetic equator. As we have stated during the major magnetic storm of October 22-23, a long lasting plume was detected by the Jicamarca radar. This plume produced ionospheric effects which could be traced to turbulence at over 2000 km above the magnetic equator. Two other areas of interest which emerged from the month long analysis were (1) the occasional presence in the 02-06 local time period of plume structures with data available from optical observations as well as from phase and amplitude scintillations and (2) the tendency for localized mid-altitude irregularity structures to be concentrated during the latter half of the month in days after the major magnetic storm; during that period there were continuing weak variations in Dst.

There is difference between stations at various latitudes and longitudes for this South American grouping. The localized differences are considerable so that on some days the occurrence of scintillation was different for stations 500 km apart.

POST MIDNIGHT-PREMORNING IRREGULARITIES

During a number of nights it was found that there were irregularities noted on optical, radar, and scintillation data in the local time period 02 (07 UT) onward. Plumes were observed on radar for the UT dates of October 3, October 4, and October 5. The data for October 4 has been analyzed in detail. For October 4 both amplitude and phase scintillation records showed very low levels near the sunset time period; only later in the evening were scintillations detected. However Spread F from ionosonde recorders was reported for the time period 0330-06 LST. For the same time period, both amplitude and phase scintillations were noted. Phase fluctuation data show moderate level phase fluctuations from 04-06 LST for October 4th which was a magnetically quiet day. The amplitude scintillation data from Tucuman and from Ancon showed activity on Satellites #7, #14 and #18 with #18 showing low levels from 0330-0430 LST but very high levels 0430-0510. The evidence of the Tucuman airglow depletion set essentially gives the origin of the irregularities i.e. they come in from the west. The use of the all-sky method is striking for forecasting. In principle the GPS paths should yield all-sky possibilities. In practise the field equipment tracks satellites which at equatorial latitudes have north-south or south-north paths.

FORECASTING

We have stated in previous reports that ground measurements can be used in real time to determine (1) scintillation activity on a particular day (with the eastern station data being used to determine if development will proceed westwards as the sunset line moves) (2) the height of the plume will tell us how far in latitude scintillations will occur.

From the scientific point of view it is vital to find the necessary and sufficient conditions for various types of plumes to develop; this approach needs real time measurements of parameters such as horizontal and vertical electron density gradients, observations of gravity waves, and perhaps measurement of atmospheric conditions below 100 km.

AASERT PROGRAM

The optical program in the equatorial region is funded under this contract; both routine and campaign observations are made. From the October 1996 campaign the 6300 A measurements showed that only the all-sky imager could determine when a new plume developed or when an already developed plume came across the radar which can only observe overhead irregularities. In July 1996, the imager situated at Goose Bay, was retrieved by Ms. Colerico and refurbished at Boston University. It was deployed to Tucuman, Argentina, in September 1996, in order to further study equatorial F-region irregularities (such as airglow depletions), which may cause loss of lock or fading of signal in GPS systems. In the past year Ms. Colerico has overseen the operation of the Arequipa, Peru imaging systems and she is now overseeing the operation in Tucuman as well. The data for the October 1996 campaign have been reduced. A first look of the Tucuman data shows interesting examples of bifurcated airglow depletions as well as possible Brightness Wave Events such as those reported on in Colerico et al. 1996. The winds studied by this technique involved are of importance relative to forecasting irregularities. Temperature enhancement at the time of passage of the Brightness Wave would have associated with it a region of increased pressure which would serve to reverse the meridional wind. Ms. Colerico has co-authored a paper which has been accepted for publication in the Journal of Atmospheric and Terrestrial Physics.

CAMPAIGN RESULTS

Two plumes generated in a short time: importance of optical data

Importance of magnetic storm activity in this period of the sunspot cycle.

Order of magnitude comparisons of phase and amplitude scintillation.

Uses of wide spacing forecasting...
Kourou and Brasilia in solar minimum years
Santiago and Ascension in solar maximum years

Days of phase fluctuations greater than plus and minus 1 TECU per minute: Arequipa had 8 days, Bogota had 3 and Santiago had 2.

FUTURE STUDIES

As we have stated phase fluctuations as noted from an equatorial station such as Arequipa, Peru can be observed from Arequipa at various latitudes north and south of the magnetic equator. These tell whether we have noted a thin layer of irregularities or a very high altitude plume. We then know how distant the effective turbulence will be felt. This is an important step in forecasting scintillation activity in a local area.

It is vital to correlate intense scintillation activity as determined by optical data and IGS analysis with loss of lock for GPS receivers. While some periods of magnetic storms noted at high latitudes did force the loss of lock, other periods failed to lose lock in sophisticated receivers. We shall be continue to determine if scintillation activity on one path can be used to forecasting scintillation activity on a series of paths.

PUBLICATIONS

GPS Phase Fluctuations in the Equatorial Region during Sunspot Minimum, J. Aarons, M. Mendillo, and R. Yantosca, Radio Science, 32, 1535-1550, 1997

Imaging Science Contributions to Equatorial Aeronomy : Initial Results From the MISETA Program, M. Mendillo, J. Baumgardner, M. Colerico, D. Nottingham, Accepted January, 1997 J. Atmos. Terr. Physics